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THE TEMNOSPONDYLOUS AMPHIBIA AND A NEW SPECIES OF *ERYOPS* FROM THE PERMIAN OF OKLAHOMA.

BY ROY L. MOODIE.

(Contribution from the Zoölogical Laboratory, No. 189.)

Plates XLIX to LIV.

OUR knowledge of the fossil Amphibia begins with Dr. J. J. Scheuczer's discovery of two skeletons in the Miocene of Oeningen, which he referred to as "*Homo diluvii testis et Theoskopos,*" and which later Hermann von Meyer designated "*Andrias scheuczeri,*" thus keeping the same idea in the generic name as Scheuczer had expressed in his letters and descriptions. The discovery was made about 1725, so far as I can ascertain. His letter to Sir Hans Sloane in 1726, which was translated in the republished volume of the early transactions of the Royal Society of London, is the first definite mention I find of this discovery in the literature which is accessible to me.

Exactly one hundred years elapsed from the time of Scheuczer's discovery of the giant salamander skeletons to the time when Dr. Georg Friedrick Jaeger discovered in the Triassic of Germany some labyrinthodont remains which he figured and described in his folio published in 1824 at Stuttgart with the title "De Ichthyosauri sive Proteosauri Fossilis Specimenibus in Agro Bollensi in Wurtembergia." He figured the occipital portion of the skull and teeth of what he, in 1828, called "Mastodonsaurus." In 1833 Doctor Jaeger pointed out the synonymy of *Salamandroides* with *Mastodonsaurus*. Previous to

Doctor Jaeger's discovery, however, was that of the form *Pygopterus,* the history of which is given below.

The literature on fossil Amphibia for the next twenty years following Jaeger's last mentioned paper deals almost entirely with the Tertiary Amphibia, although in 1844 and 1845 Hermann von Meyer published some interesting papers on the more ancient amphibians. It is interesting to note that in von Meyer's "System der fossilen Saurier," 1845, he does not mention a single temnospondylous amphibian.

Our knowledge of the Temnospondylia dates from the year 1847, in which year Dr. August Goldfuss described *Archegosaurus,* the first known and for many years the only representative of this order of amphibians. Doctor Goldfuss gave as the title of the paper in which he described *Archegosaurus* "Ueber das ælteste der mit Bestimmtheit erkannten Reptilien." It will thus be noticed from the literature that the early writers regarded the labyrinthodonts and their allies as reptiles. It was Quenstedt who in 1850 made the first contention that "Die Mastodonsaurier im gruenen Keuper Sandstein Wurtemburgs sind Batrachier," and from that time dates the development of our knowledge of these extinct forms as Amphibia. Three years after Quenstedt's paper appeared, Vogt upheld the same contention in his essay "Archegosaurus und all Labyrinthodonten sind Amphibien nicht Reptilien."

In 1850, after the discovery of the *Archegosaurus* and its identification, Doctor Jaeger published an interesting essay entitled "Ueber die Uebereinstimmung des *Pygopterus lucius* Ag. mit dem *Archegosaurus dechenii* Goldf." In this essay Jaeger brings out the interesting facts of the early discovery of the *Archegosaurus.* I give the following translation of the first paragraph of Jaeger's essay: "In the collection of the late Professor Storr, of Tübingen, which was received in 1817 at the Imperial Museum of Natural History at Stuttgart, there was found a skull enclosed in a spherosiderite nodule. This skull was listed in 1777 as No. 192, in the printed catalogue of the Pasquay collection (which was the foundation of the Storr collection), without giving the locality, as a fish skull which had been discovered in a non-fissile gray shale. Agassiz, at whose disposal the entire collection of fossil fishes was soon after placed, designated this specimen on a label in his own handwriting at first as *Aspidorhynchus* nov. sp. On a label written

by him later it is designated as *Pygopterus lucius*. In the first part of the second volume of the Fossil Fishes (Poissons fossiles), page 10, Agassiz placed this skull in the family Sauroidæ as the second species of the genus *Pygopterus*, with the short description: '*Pygopterus lucius* Ag., une tête seulement, dont la mâchoire supérieure est plus allongée. Houille de Saarbrück.' In the same work, part II, page 78, this specimen is designated as the fifth species of *Pygopterus*, with the description, 'une tête avec des dents très acerées, de la houille de Saarbrück. L'original se trouve au Musée de Stuttgart.' He regards the same specimen as the third species on page 162 in the synoptic table of the family Sauroidæ arranged in the order of the formations of the Carboniferous which contained Sauroidæ. It is also given this place in the general table of fossil fishes which appeared in 1844, page xxxvi."

Jaeger affirmed the supposition of Agassiz that the specimen was from Saarbrück, from the similarity of the nodule to those found at that place. He then proceeded to show that the skull described by Agassiz as *Pygopterus lucius* really shows reptilian characters which Jaeger regarded as intermediate between those of a crocodile and an *Iguana*. He then compared it with the skull of a young crocodile and also with the skulls of various lizards. He found that the measurements and proportions of the skull compare favorably with those of the crocodile, and that the teeth have the form and size of those of a newly born crocodile. The position of the orbit is also identical with that of the crocodile. He made the important observation that the nostrils have the lateral position of the lizards. He then compared the specimen with other known fossil forms, *i. e.*, *Zygosaurus*, *Rhinosaurus* and the labyrinthodonts, and found considerable differences. He then made the following interesting observations regarding *Archegosaurus*: "At the meeting of naturalists in Aachen in 1847 Goldfuss described the remains in one of the many spherosiderite nodules, which contained a reptile skull, to which he gave the name *Archegosaurus*. He established three species for the genus, which he described more fully in a later publication. Only one species of this genus, *Archegosaurus decheni*, was described and figured in the Neues Jahrbuch für Mineralogie, 1847, Tab. VI, with a line drawing." Jaeger then pointed out in a conclusive manner the identity of *Pygopterus lucius* with *Archegosaurus*. He re-

garded *Archegosaurus* as allied to the Crocodilia but having characters of the Batrachia as were exhibited in the labyrinthodonts, and on account of the geological position of the fossils he supposed that *Archegosaurus* would really belong with the labyrinthodonts.

Huxley in 1862 described *Pholidogaster pisciformis* from the Carboniferous of Scotland. In the next year he distributed the ancient Amphibia into the two groups, the Archegosauria and the Mastodonsauria of von Meyer. In the former group he placed *Pholidogaster,* to which it manifestly does not belong. Huxley was himself doubtful as to its location, for he says: "*Archegosaurus,* of course, takes its place among the Archegosauria; and *Pholidogaster,* I suspect, must go with it, though its vertebræ are far better ossified"; and in a footnote he makes the interesting statement: "It seems to me probable that the vertebral centra of *Archegosaurus* may really have been osseous rings, such as are found in embryo frogs and salamanders," which shows that he was on the right track but did not quite comprehend the nature of the vertebræ of *Archegosaurus.*

Our knowledge for the next few years of our history is advanced but little, and that only by sundry discussions on *Archegosaurus.* In 1866 Owen placed *Archegosaurus* in his subclass "Dipnoa," under the order "Ganocephala." In the same year Haekel retained Owen's classification, except that he displaced Owen's "Dipnoa" with "Phractamphibia." Cope, in 1868, retained essentially the same classification as proposed by Owen. In 1874 the committee of the British Association for the Advancement of Science reported on the extinct Amphibia, and placed *Archegosaurus* by itself in group VI, the Archegosauria.

No further additions were made to our knowledge of the Temnospondylia until 1875 and 1878, when Cope described *Cricotus* from the Carboniferous of Illinois and *Trimerorhachis* from the Permian of Texas. In the next year Gaudry described *Actinodon* from the Permian of France. In 1882 a decided advance was made in the separation by Professor Cope of the rhachitomous forms such as *Eryops, Actinodon, Zatrachys, Trimerorhachis* and other genera, which have subsequently proven to be synonyms of the genera mentioned, into a distinct group. Cope proposed the term Rhachitomi for this subordinal group, and designated two families, the Eryopidæ and the Trimeror-

hachidæ as its members. Later in the same year Cope described *Acheloma* from Texas. In 1885 Lydekker added other genera and families to the group, notably *Gondwanosaurus*, which he placed in the family Archegosauridæ. In 1884 Cope, and in the following year Fritsch, contributed further to the knowledge of the Temnospondylia by the description of the forms *Diplospondylus* and *Cricotus* from the Permian of Bohemia and Texas. In 1888 Zittel proposed to place all temnospondylus amphibians under the suborder Temnospondyli in two groups—A, those with rhachitomous vertebræ; B, those with embolomerous vertebræ—for which two groups Cope had previously, 1885, proposed the terms Rhachitomi and Embolomeri, but had regarded them as coördinate with the group Stegocephali.

Case, Broili, and others have in recent years given additional information on the forms previously described and have described some new forms. In 1909 Dr. S. W. Williston, in his essay on "*Trematops milleri* from the Permian of Texas," was enabled to give a restoration of the skeleton of that form. In the present bulletin the writer will describe an interesting new embolomerous amphibian under the name *Spondylerpeton spinatum*, from the Coal Measures of Mazon Creek, Illinois. This is the oldest of the known Temnospondylia.

We know nothing of the ancestry of the Temnospondylia. They occur in the Carboniferous and Permian, and if the Stereospondylia are highly specialized Temnospondylia, as seems probable, they also occur in the Triassic, but this is yet to be proven.

The geographical distribution of the Temnospondylia is as follows: In the Carboniferous and Permian of North America; Europe; and Asia, in the Permocarboniferous of India, *Gondwanosaurus*. So far as the writer is aware they occur nowhere else unless some of the little known forms from South Africa will, on further search, reveal temnospondylous characters. It is entirely too soon to arrive at any conclusions as to the paths of migration of this group. They followed the way which was open to other land animals, whatever that may have been.

Nor can we say in what region the first of the Temnospondylia lived. Judging from the remains so far discovered their place of origin must be located in North America. The announcement of the discovery of the eryopoid form from Pitts-

burg, Pa., by Case, and the discovery by the writer of the cricotoid form in the Mazon Creek fauna, as well as the presence of Carboniferous Cricotidæ in Illinois and Kansas, all point to an origin of the temnospondylous group at an earlier date in North America than in any other region of the globe. The embolomerous forms are by far the older.

The species of fossil Amphibia from the Carboniferous, Permian and Triassic are so little known that it is difficult to give a definite list of the species of the Temnospondylia. The list given below is believed to be approximately accurate. It does not differ in essential outlines from that given by Zittel in 1887. The species are distributed in the various groups to which, at the present time, they seem to belong:

CLASS—AMPHIBIA, LINNÉ, 1758.

ORDER—TEMNOSPONDYLIA, Zittel, 1887.
Suborder—RHACHITOMI, Cope, 1885.

FAMILY—ERYOPIDÆ Cope, 1882.

Eryops megacephalus Cope, 1877. Permian of Texas.
" erythrolithicus Cope, 1878. Permian of Texas.
" ferricolus Cope, 1878. Permian of Texas.
" reticulatus Cope, 1881. Permian of Texas.
" ? platypus Cope, 1877. Carboniferous of Ohio.
" latus Case, 1905. Permian of Texas.
" willistoni Moodie, 1911. Permian of Oklahoma.
Trematops milleri Williston, 1909. Permian of Texas.
Acheloma cumminsi Cope, 1882. Permian of Texas.
Ichthycanthus ohiensis Cope, 1877. Carboniferous of Ohio.
Gondwanosaurus bijoriensis Lydekker. Bijori, India.
Zatrachys apicalis Cope, 1881. Permian of Texas.
" conchigerus Cope, 1896. Permian of Texas.
" crucifer Case, 1905. Permian of Texas.
" micropthalmus Cope, 1896. Permian of Texas.
" serratus Cope, 1878. Permian of Texas.
Actinodon frossardi Gaudry, 1880. Permian of France.
" latirostris Jordan. Permian of France.
* (?) Anisodexis enchodus Cope, 1897. Carboniferous of Ohio.
* " imbrecarius Cope, 1882, Permian of Texas.
*Rhytidosteus capensis Owen, 1884. Karoo Beds, South Africa.
(?) *Euchirosaurus rochei Gaudry. Permian of France.

FAMILY—TRIMERORHACHIDÆ Cope, 1882.

Trimerorhachis bilobatus Cope, 1883. Permian of Texas.
" conangulus Cope, 1896. Permian of Texas.
" insignis Cope, 1878. Permian of Texas.
" mesops Cope, 1896. Permian of Texas.
" leptorhynchus Case, 1902. Permian of Oklahoma.
Cricotillus brachydens Case. Permian of Oklahoma.
Archegosaurus austricus Makowsky, 1876.
" decheni Goldfuss, 1847. Permian of Germany.
" latifrons Gein. & Deich. Permian of Saxony.
" ornatus Woodward, 1905. Permian of India.

Platypodosaurus ricardi Twelvetrees, 1880. Permian of Russia.
" stückenbergi Trautschold. Zechstein of Russia.
Cochleosaurus bohemicus Fritsch, 1876. Permian of Bohemia.
Gaudrya latistoma Fritsch, 1885. Permian of Bohemia.
Chelyosaurus vranyi Fritsch, 1878. Permian of Bohemia.
*Sphenosaurus sternbergi Fitzinger, 1840. Permian of Bohemia.
Sparagmites lacertinus Fritsch, 1885. Permian of Bohemia.
*Sclerocephalus hauseri Goldfuss. Permian of Germany.
*Sclerocephalus credneri Fritsch. Permian of Bohemia.
*Sclerosaurus bavaricus Branco. Rothl. Ohmbach.
*Melosaurus uralensis H. von Meyer. Kupfersandstein.
*Osteophorus roemeri H. von Meyer. Rothl. Schliessen.
*Zygosaurus lucius Eichwald. Permian of Russia.

Gonioglyptus huxleyi Lydekker from the Gondwana beds of India also possibly belongs in this family.

So many genera and species of extinct Amphibia are based on fragments of crania or limbs that an exact diagnosis of the forms is impossible. The species marked with a star (*) are uncertain as to position. Many of the species listed under the Trimerorhachidæ are placed in this family on the authority of Lydekker, who included them in his family Archegosauridæ, which was preoccupied by Trimerorhachidæ. Doctor Williston regards *Trematops milleri* Will. and *Acheloma cumminsi* Cope as representatives of a family distinct from the Eryopidæ for which in 1910 he proposed the name Trematopsidæ. He also regards the species of *Zatrachys* as entitled to family rank in the Zatrachydidæ, Williston, 1910.

Euchirosaurus of Gaudry is probably a reptile.

Suborder—EMBOLOMERI, Cope, 1881.

FAMILY—CRICOTIDÆ Cope, 1884.

Cricotus gibsoni Cope, 1877. Carboniferous of Illinois.
" crassidiscus Cope, 1884. Permian of Texas.
" heteroclitus Cope, 1875. Carboniferous of Illinois.
" hypantricus Cope, 1884. Permian of Texas.
" sp. indet. Case. Carboniferous of Illinois.
Diplospondylus punctatum Fritsch. Permian of Bohemia.
Spondylerpeton spinatum Moodie, 1910. Carboniferous of Illinois.
? *Discosaurus permianus Credner. Permian of Saxony.

FAMILY—DISSOROPHIDÆ Williston, 1910.

Dissorophus multicinctus Cope, 1895. Permian of Texas.
" mimeticus Cope, 1896. Permian of Texas.
" testudineus Cope, 1896. Permian of Texas.
Cacops aspidephorus Will. 1910. Permian of Texas.
Aspidosaurus chiton Broili, 1904. Permian of Texas.

From the foregoing diagnosis is will be seen that about 55 species of the 350 which have been assigned to the fossil Amphibia of the world can be located in the order Temno-

spondylia. Without doubt some of these species will prove invalid and there will be others already described which will in time prove to belong to this group, but the above statements represent an approximation of our present knowledge.

Since the present essay is to deal especially with a new member of the genus *Eryops*, only those groups will be here defined to which *Eryops* and its allies pertain.

ORDER—TEMNOSPONDYLIA, Zittel, 1887.

Terrestrial or semiaquatic vertebrata; skull bones pitted and grooved; lateral line canals present; pineal foramen sometimes absent; sclerotic plates present; vertebræ rachitomous or embolomerous; notochord usually persistent; one or two sacral vertebra; tail present, short or long; limbs and girdles all well developed; pectoral and pelvic girdles composed of the usual stegocephalan elements; an osseous pubis present; cleithrum present on the scapula in some forms; limb bones well developed and bones of forearm and leg separate; carpus and tarsus osseous, 12 elements present in tarsus of one form, 11 carpals; five digits in hand and foot; phalangeal formula 2, 3, 3, 4, 2 (?) for the hand and 2-3-3-3-2(?) for the foot; venter covered with an armature of osseous scutes, sometimes overlapping; skin of back bare or armored; ribs heavy, double-headed, curved, and either moderately long or short. Body short and heavy. As compared to skull, about two to one. Temporal foramina present in a few forms.

Range. Pennsylvanian to (Triassic) Upper Permian.

Distribution. North America—Illinois, Kansas, Oklahoma and Texas. Europe—Germany, Bohemia, France. Asia—India.

The suborder Rhachitomi is characterized solely by the nature of the vertebral column, which is cut into triangular segments.

FAMILY—ERYOPIDÆ Cope, 1882.

Large terrestrial or amphibious vertebrata; skull bones deeply marked with pits and grooves which at times take the form of lateral line canals; carpus and tarsus osseous; pubis osseous; pentadactyl fore and hind limbs; orbits in the typical genus located far back on the skull and near the median line; cleithrum present on the scapula; vertebræ rachitomous, the intercentrum supporting the arch in the dorsal region; para-

sphenoid well developed or reduced; teeth on pterygoids, palatines, prevomers and parasphenoid.

Range. Upper Pennsylvanian to Permian.

Distribution. America, Europe, Asia.

Genus—Eryops Cope, 1877.

The following definition of the genus is given by Doctor Branson: "Skull long, comparatively narrow; proportion of length to breadth about nine to seven. Roof bones coarsely sculptured posteriorly, finely sculptured anteriorly. Nasals and premaxillæ very large; frontals excluded from orbits by junction of pre- and post-frontals. Pterygoids not meeting in the median line; parasphenoid dagger-shaped, tapering gradually to a point just in front of the palatine foramina; prevomers large. Orbits subcircular, situated in the posterior half of the skull; nares subovate, remote, at a considerable distance from the tip of the skull. Many minute denticles on pterygoids, palatines, prevomers and parasphenoid. Teeth circular in cross section, strongly ribbed near base, dentine strongly infolded. Three large teeth on each palatine. Mandible without postcotyloid process. Vertebræ rachitomous. Ribs double-headed. Pelvic bones coalesced."

There have been up to the present five species of *Eryops* described, with a doubtful sixth, ? *Eryops platypus* Cope, from the Carboniferous of Ohio.

In 1889 Lydekker described a species of *Eryops, E. africanus,* from the Karoo beds of South Africa. Broom has subsequently shown that this species does not belong in this genus and has placed that species with two others in his genus *Rhinesuchus,* in which he includes *R. (Macromerion) gumbeli* (v. Ammon), *R. (Eryops) africanus* (Lydekker), and *R. whaitsi* Broom.

An additional species of *Eryops* is represented by remains in the collection of the University of Kansas and it is here described as new.

Eryops willistoni, new species.

Dr. S. W. Williston in 1899 described and partially figured in the *Kansas University Quarterly* portions of a skeleton of a species of *Eryops,* which he tentatively referred to the species *Eryops megacephalus* Cope. He has several times expressed to me the opinion that the form is distinct from *E. megacephalus,* and a recent careful study of the ma-

terial has led me to regard the remains as a new species, which may be very appropriately named *Eryops willistoni* as a partial expression of gratitude to my honored preceptor in paleontology. Since, also, several interesting points in anatomy and morphology have come up for consideration the following discussion is presented in the hope of adding some knowledge on this peculiar Permian genus.

The material which represents the present species comprises the following portions of the skeleton: Portions of the skull; several teeth and a nearly entire right mandible; the scapula-coracoid of both sides, incomplete; the right clavicle; portion of the interclavicle; right humerus, radius, ulna and a phalange; about a dozen vertebræ and the left sacral rib.

There are various fragments of the skull preserved. On one of these fragments is observed a portion of the right orbit and a part of the prefontal and frontal bones clearly marked off by sutures. The present form differs in this respect from the known specimens of *Eryops megacephalus,* in which the sutures remained unknown until they were discovered by Doctor Branson, who was able to trace them with the aid of a lens. On the present specimen the sutures stand out with almost startling distinctness. They do not have the sharply zigzag form assumed in *E. megacephalus* and other of the larger Amphibia, but the sutures occur in bold curves. I detect a portion of the supraorbital lateral line canal on the fragment containing the orbit. The sculpture of the cranial bones in the present form is quite different from that of *E. megacephalus.* It is much more rugose and the rugosities have a larger form. This holds true for the mandible also (plate XLIX, fig. 1), and it is taken as one of the specific characters.

There are preserved in the collection also a single complete tooth and fragments of others. The complete tooth (plate XLIX, fig. 2) is of the typical labyrinthodont form. It is oval in cross section with sides flattened. It arises from a tumid base of cancellated bone as in the mosasaurs. It is recurved and sharply pointed.

In 1899 Ludwig Strickler (Paleontographica Bd. XLVI, p. 85, plates XI, XII) investigated the minute structure of the teeth of *Eryops megacephalus.*

The mandible of the present species is preserved in a much broken condition, but its form is nearly complete. The form and ornamentation of the posterior portion were well shown in

Williston's figure (Kan. Univ. Quart., Ser. A, vol. VIII, pl. XXX, fig. 1), which is reproduced here with slight changes. The sharp angulation and the posterior position of the angle is a specific character which serves to distinguish this species from *Eryops megacephalus* Cope, to which the present form is most nearly allied.

The jaw (plate XLIX, fig. 1), is heavy and elongate. The portion posterior to the coronoid angle is an acute triangle which ends in the articular. Only a portion of the suture bounding the articular can be distinguished. This is indicated in the figure. The coronoid suture is evident for its entire course. The suture starts from the articular suture, and running directly forwards turns upward just before reaching the teeth, which do not occur on the coronoid. This element is a thin bone superiorly but more thickened below. The sutures separating the angular, surangular and dentary cannot be determined. The angular and surangular contain, on their external surface, the peculiar nodose ornamentations which help to characterize the present species.

The sculpture on these elements consists of scrobiculate knobs some 5 to 7 mm. in diameter. This ornamentation ends apparently at the dentary, since the tooth-bearing element, which is quite large, is ornamented only with coarse elevations and pits.

The operculo-mandibular lateral line canal can be traced as a depression beginning on the articular and running forward as far as the bone is clearly preserved. It occurs as a shallow groove interrupted by the nodose and scrobiculate sculpturing of the mandibular elements. The internal surface of the mandible is not preserved in sufficient detail for description.

Complete teeth are lacking from the mandible in its present condition. Doctor Williston figured two of them as complete, and it is quite probable that they have been broken off since he studied the specimen, because the material is excessively fragile. The hollow character holds for all of the tooth bases which are preserved on the mandible. An additional portion of the mandible is shown in figure 5, plate XLIX. Its characters do not differ from those described above.

In regard to the hollow nature of the teeth, Tomes has the following explanation: "The laminæ of pulp, with their several systems of dentinal tubes, instead of passing out in straight

lines like the spokes of a wheel, pursue a tortuous course as they run from the central small pulp chamber toward the surface. Not only do they undulate, but they give off lateral processes, and at their terminations near the surface of the tooth the thin laminæ of pulp (so thin that the radiating pulp chambers are mere fissures) become dilated; so that on section circular canals are seen at these points, as is also the case at the points where subsidiary processes branch off." (Dental Anatomy, 5th edition, 1898, p. 65.)

Measurements of the mandible of *Eryops willistoni:*

Greatest length	48 cm.
Length of posterior portion (fig. 1)	33
Greatest width	10
Width of dentary midway from coronoid process	6.5
Width across articular	2.6
Length of tooth	2.
Thickness of same at base	.5

The right arm of this species is preserved in an incomplete condition, as may be seen by reference to plate LII. The form of the humerus is well shown in the figures, plate LIII, fig. 7, and plate LII. It suggests to a certain extent the humerus of a mosasaur. The present element does not have the bizarre appearance which exists with the specimen of that element of *Eryops megacephalus* figured by Professor Cope in 1890 (Trans. Amer. Philos. Soc., vol. XVI, p. 367, fig. 3). The large projections are wanting entirely from one side and on the other they are not so highly developed, and yet the form of the bone is such that it can be nothing else save a humerus. It is too rugged for a femur.

The specimen is abraded to some extent, so that the exact form of the element cannot be determined. It may have had the form suggested by the broken lines in the figures. The humerus is that of the right side. Viewed from in front the element is seen to have a peculiar form (plate LIII, fig. 7). The lower portion of the inner surface is distinctly concave. The inner side of the bone is comparatively smooth. There is a low ridge which runs obliquely across the antero-superior angle of the bone. There is a distinct twist in the inner surface, which is continued to such an extent that the inner surface is carried around almost parallel with a portion of the outer surface. It then takes another and inward curve and ends in a projection.

One of the projections from the outer surface of the humerus

is in the form of a hook and strongly suggests the hooklike process which is developed in the quadrate of the mosasaurs. This hook and the other elevations on the edge of the bone without doubt served as points of attachment of the deltoid and pectoralis muscles, which were undoubtedly well developed in the species of *Eryops*.

The outer surface of the bone is exceedingly rough and there are no less than six distinct elevations on this surface. One of these elevations is a ridge which runs at somewhat of an angle across the posterior edge. There is an indication of a foramen opposite the pit which occurs on one side of the bone, which at first was thought to represent the entepicondylar foramen. This was such an important matter that the bone was cut through at this point by Mr. Martin and fully demonstrated the total absence of this foramen in the element although there is quite a distinct pit at this point. Cope described such a foramen in *Acheloma*, but Case, who has recently examined the type, says the foramen is an accidental opening. Gaudry likewise described such an opening in *Actinodon*.

Measurements of the humerus:

Length of specimen as preserved	96 mm.
Estimated length along same line	110
Width at middle of shaft	50
Width of top of humerus	90
Width at lower end	72
Thickness of head as preserved	23
Diameter of entepicondylar pit	3

The element which is here regarded as a radius is very similar in form to that described by Cope for *Eryops megacephalus*. Its form is well shown in the figure. The lower end is somewhat larger than the upper, which is abraded and broken. Viewed from the lower surface a cross section of the bone shows a semicircular form. It is hour-glass shaped in its entire length, with a shallow groove near the lower end. Both ends of the bone near the articular surfaces are roughened by vascular pits for muscular attachment or for the union of the cartilaginous tips.

Measurement of radius:

Actual length of specimen	91 mm.
Estimated length of specimen	95
Width of upper end (estimated)	40
Width at middle of shaft	24
Width at lower end	60
Thickness of base	32

The element here figured as an ulna (plate LII, *U*) is doubtfully referred to the arm, since the bones were found disassociated. It may belong to the leg. Its form is specifically different from that which Cope figured as the ulna of *Eryops megacephalus*, although its form is, in general, the same. It does not depart widely, in point of form, from that of the radius, which we should expect to be the case in a generalized vertebrate. It is smaller, somewhat shorter, and the groove on the ventral (?) surface is lacking. The radius and ulna are both peculiarly amphibian in the way they have weathered. The ends have assumed the concave form so characteristic of the Branchiosauria and the modern Amphibia, indicating a higher development of the perichondrium than of the endochondrium.

Measurements of the ulna:

Actual length of specimen	80 mm.
Estimated length of specimen	93
Width of shaft at middle	22
Width of upper end (estimated)	47
Width of lower end (estimated)	40

Associated with the limb bones there is a portion of a phalange of the hand (?) of the specimen. There are no carpals preserved. The element figured (plate LIII, figs. 4 and 5) is probably a metacarpal. Its form is very closely similar to that figured by Cope for the metacarpal element of *Eryops megacephalus*. Its upper end is very broad, with recurving edges and with rugosities for muscular attachment. Its form is crescent shaped and concave. The shaft narrows abruptly from the upper end to the middle and then widens for the lower end, which is lost.

Measurements of the metacarpal:

Actual length of specimen	23 mm.
Estimated length of bone	27
Width of upper end	22
Thickness of upper end	8

The following description of the coraco-scapula (plates L, LI) is taken from Doctor Williston's paper. The description of the cleithrum is appended:

"The bone is elongated, and nowhere very thick or massive. The distal part of the scapula is much thinned and considerably expanded; the immediate margin here, however, is wanting, so that the precise outlines cannot be given.

"The position of the two bones must have been very oblique, as is evident from the position of the glenoid cavity. The pos-

tero-inferior border is moderately thickened, and rounded; gently concave along the proximal part and convex distally. The antero-superior border is much thinner than the opposite one, and is concave throughout the extent of the shaft, except distally, where it is coössified with the procoracoid. The union of these two bones is very close in this region, the sutural line being distinguished with difficulty if at all. The procoracoid is narrower and more thickened below, reaching to the lower part of the conjoined bone, and lying in close apposition though not suturally united. Both the lateral surfaces of the scapula are nearly flat. A little proximad to the narrowest part of the shaft the bone is much thickened by a stout ridge on the inner side, which includes between it and the remainder of the bone, just back of or above the cotylus, a large, elongated foramen, both of whose orifices can be seen from the inner side of the bone only.

"The glenoid surface is elongated and deeply concave in its long diameter. The scapular portion is much smaller than the coracoid, and is partly separated from it by a constriction; this surface is nearly flat and is placed at right angles to the plane of the coracoid surface, looking directly downward when the bone is lying horizontally. The rest of the cotylus is moderately concave and looks outward and somewhat backward and upward with the bone in its former position. Just how much of the conjoined bone is formed of each element it is impossible to say since the union is so close that no trace of a junction is perceptible. Evidently, however, the coracoid forms only a small part of the whole bone. Its anterior or inferior border is gently convex, the posterior one slightly concave.

"The anterior end of the superior border of the scapula is gently convex, as is also the broad external surface. On the inner side the foramen described above opens into a deep, elongated, boat-shaped cavity at its distal end, the cavity formed by the upper border of the ridge described. In the lower or anterior end of the cavity there are apparently two smaller foramina, the external orifices of which are just within the anterior margin of the scapular face of the glenoid surface. The proximal surface of the scapula is concave; that of the coracoid, if the bone is limited by the ridge spoken of, is for the most part gently convex and lies in a more mesial plane."

The scapula is evidently that of the right side, the same as the humerus described below.

On the antero-superior corner of the scapula is a part of a peculiar element—the cleithrum. Its occurrence in the genus *Eryops* has been noted by Case in two species. In *E. latus* the cleithrum takes a most peculiar form. The form assumed by the element in the present species is impossible to determine, since the greater part of it has weathered away.

The cleithrum is, apparently, simply laid on the upper edge of the scapula, the union being hardly a sutural one. In the present specimen it is represented only by the lower part, but it could not have had the immense expanse superiorly as Case and Williston have figured for the cleithrum in *Eryops latus* Case. It was probably quite slender, as it is in the dicynodont reptiles. The cleithrum is a thin plate of bone with a ridge running along the interior border. The edge of the scapula is depressed to receive the element.

The characters of the scapula which are at variance with the scapulæ of the known species are the narrowness of the shaft, the location and size of the cleithrum, and the position of the cotylus.

In regard to the three foramina seen and described in the scapula Williston has recently proposed the terms supra-, post- and infra-glenoid or supra-coracoid to designate these openings. The foramina occur in all known Temnospondylia, as well as in the Cotylosauria (2) and in the Pelycosauria (2). The writer has recently described a branchiosaurian from the Pennsylvanian of Mazon Creek in which three foramina are visible in the scapula. This was thought to be of interest in connection with the Temnospondylia, but investigation showed that in the temnospondyles the foramina are in no case to be regarded as occurring strictly in the scapula, but rather as belonging to the coracoid which is united with the scapula.

An interesting question of homologies, or it may be parallel development, arises in comparing the present scapula-coracoid with the clavicular apparatus of *Portheus*.

Measurements of scapula-coracoid:

Actual length of specimen	33.7	cm.
Estimated length of element	36	
Width of upper end of scapula	15.5	
Thickness at upper end	3	mm.
Width at middle of shaft	6.6	cm.
Width across coracoid portion	17	

Length of cotylus	7.2	
Width of cotylus	3.8	
Diameter of infraglenoid foramen	5	mm.
Thickness of bone at lower edge	7	
Thickness of bone through cotylus	4.3	cm.
Length of portion of cleithrum preserved	63	mm.
Greatest width of cleithrum	22	

The clavicle of the right side is preserved almost completely (plate LIII, figs. 1 and 2). The element was figured by Doctor Williston but not described. It is strongly curved and spatulate. Its outer surface is ornamented with longitudinal grooves, which arise near the center of the bone and run each way, thus indicating its ossific center. The inner surface of the bone is smooth excepting for two vascular pits near the center. A prominent ridge runs along the dorsal inner edge of the bone.

Measurements of the clavicle:

Length along curve	24.7	cm.
Length across arc	20	
Least width	1.3	
Greatest width	4.6	
Greatest thickness	1	
Least thickness	2	mm.

There is a fragment of what I regard as the posterior projection of the interclavicle. If it is such it is either a pathological specimen or there were two projections from the posterior edge of the interclavicle, for the fragment is highly asymmetric. The spine, for such it is, has an irregular nodose surface as if for the attachment of cartilage. It is long, slender and somewhat flattened. (Plate LIII, fig. 3.)

Measurements of spine of interclavicle:

Length of specimen	13.7	cm.
Greatest width	2.2	
Least width	.75	

There are remains of about a dozen vertebræ preserved. Portions of three of these are figured in plate LIV, figures 1 and 2. They all have the characteristic rachitomous form assumed by the other species of *Eryops*. The divisions between the pleurocentra, hypocentra and neurocentra are well marked. The zygapophyses are well formed. The upper part of the neural spines is much thickened, as is the case often in specimens of *Eryops megacephalus* Cope. According to Broili the spines may also be bifurcate, as Cope has described for *E. erythrolithicus*. The enlarged spine was undoubtedly for the attachment of muscles to sustain the enormous head, and

spines showing different characters might very easily occur in various portions of the vertebral column.

Measurements of vertebræ:

Length of centrum	2.5 cm.
Width of centrum	3.2
Height of vertebræ to tip of spine	13.4
Thickness of top of spine	3

Broili (Monatsb. d. Deutsch, Geol. Gesell., Bd. 60, Texttafel p. 236, fig. 2) has figured in *Eryops megacephalus* a peculiar element which he has identified as the sacral rib, having found it in place with a sacral vertebra. There is no doubt that the present element (plate LIV, figs. 3 and 4) is the same as he has figured. Its interpretation as a sacral rib is somewhat surprising on account of the extreme thinness of the bone. It thins out to less than a millimeter on one edge. Its location any other place in the skeleton is, however, doubtful.

The element has a broad base as if for attachment suturally with the vertebral transverse process. The base of the specimen has been broken transversely and only a portion of the suture remains. The bone is flat immediately from the base and is greatly expanded and thinned distally. It is, for the most part, smooth, though there is a small roughened place on the dorsal (?) surface. The ventral (?) surface is marked by a depression which runs the entire length of the bone. The distal end is lost.

Measurements of sacral rib:

Actual length of specimen	90 mm.
Width at distal end	62
Width at middle of blade	32
Width at inner end	55

Eryops willistoni differs from *E. ferricolus* Cope in the absence of a raised rim to the orbits. From *E. erythrolithicus* Cope it differs in the non-bifurcation of the neural spines. This last is not a well-known species and may be synonymous with *E. megacephalus*. *E. reticulatus* is a small species, from which *E. willistoni* differs in the character of the cranial sculpture. It is distinct from *E. latus* Case on account of the dimensions of the scapula and the cleithrum. *E. megacephalus* also shows characters which are divergent from those of the present species. These are the shape and structure of the mandible and its ornamentation, the form of the humerus and

the shape and structure of the scapula-coracoid, as well as other structures which are characteristic.

The material on which the species *Eryops willistoni* is based is from the Permian of Oklahoma. It was collected by Prof. C. N. Gould in 1896, in the red sandstone southwest of Blackwell, Okla. The specimen is No. 348 of the Kansas University Museum.

I am indebted to Mr. G. Dallas Hanna for all of the drawings illustrating the present essay, except that on plate XLIX figure 1, which is from the pen of Mr. Sydney Prentice, at present with the Carnegie Museum.